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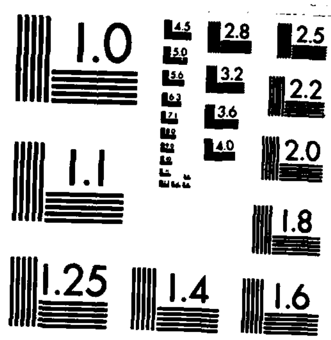

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Introduction: The Department is in the process of deploying a new satellite system for the purpose of navigation and point positioning. While designed primarily for military applications, the system poses great potential for civilian use as well. In particular, the use of GPS in a geodetic mode may yield rapid, accurate survey positions in three dimensions. Thus, in the near future, GPS will become a valuable new tool to the Corps surveyor.

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THE POTENTIAL OF THE NAVSTAR GLOBAL POSITIONING SYSTEM FOR THE CORPS OF ENGINEERS, CIVIL WORKS

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BIOGRAPHICAL SKETCH

Kenneth Robertson is a Research Physicist with the Surveying Division of the Engineer Topographic Laboratories. In that position he has developed a number of surveying techniques and instruments for use by Corps surveyors. Included in these are a method for precise monitoring of dams and an instrument for measuring the tilt of dams and lock walls. His current work is with applications of the Global positioning system and the north seeking gyro. He is a graduate of Indiana University.

INTRODUCTION

The Department of Defense is in the process of deploying a new satellite system for the purpose of navigation and point positioning. While designed primarily for military applications, the system poses great potential for civilian use as well. In particular, the use of GPS in a geodetic mode may yield rapid, accurate survey positions in three dimensions. Thus, in the near future, GPS will become a valuable new tool to the Corps surveyor.

HISTORY

Man has always used the stars to navigate or find directions and more recently to fix his position on the surface of the earth. When the first artificial satellites were put into orbit they were used almost immediately for geodetic positioning. From its beginnings in the late 50's with the use of satellite tracking cameras, the technique has evolved into the the modern systems of today with microwave transmitters on board the satellites.

The Army SECOR (Sequential Collation Of Range) and the Navy TRANSIT are examples of such electronic systems. The SECOR system was intended for precise geodetic positioning through range measurements and was only partially successful. The TRANSIT navigation satellites are still in use today for both navigation and point positioning.

THE TRANSIT DOPPLER SYSTEM

Because the TRANSIT navigation system is one which has been remarkably successful and has been adapted to the civilian sector, and because NAVSTAR may replace this system, it would be of interest to understand TRANSIT's evolution and history.

TRANSIT was developed for military use starting in 1958. It was designed to be a marine navigation aid and that remains its primary role today. However, in the late 60's equipment was developed to use TRANSIT for surveying. The most important application is for point positioning. In contrast tosatellite position fixes taken on a moving vessel in which each position fix is used independently to update the dead-reckoned position, fixed point positioning requires data from multiple satellite passes at a single location. With appropriate data processing techniques, good survey results may be obtained, thus avoiding the land traverse required by conventional survey methods. A horizontal positioning repeatability of less than 5 meters can be expected after 25 satellite passes.

A second way of using the TRANSIT satellite is in a relative or translocation mode. In this mode, data from two or more receivers are combined in such a way that the relative position between the receivers may be found to less than one meter. When one receiver is placed on a known point, the coordinates of the other point may then be accurately determined.

The federal Geodetic Control Committee has tested the TRANSIT system in the translocation mode. They say:

> "Analysis of the test results indicated that with about sixteen passes (generally one day of observations) it is possible to compute the position of an unknown point relative to a known point to an accuracy of plus or minus 40 cm for latitude and longitude and about plus or minus 1 meter for the elevation (1 sigma estimates)."

USES OF THE TRANSIT DOPPLER SYSTEM

The TRANSIT system was originally designed for navigation of ships and it is to fulfill this function that the system is mainly used. But surveying is also an important use, and the one which we are concerned with here. Following is a list of some of the present uses of TRANSIT for surveying. These are, of course, uses to which the Global Positioning System would also be put.

Seismic Line Control. TRANSIT may be used to provide control for the end points of a seismic line and for quality control of the interior part of the line where conventional control surveying techniques are currently used.

Gravity Surveys. TRANSIT provides endpoint control for gravity surveys performed with an inertial surveying system.

Control for Offshore Positioning. TRANSIT may be used to determine the exact position of offshore drilling platforms and ships.

three dimensional position of the second receiver may be determined. The number of stations determined simultaneously is limited only by the number of receivers available.

Accuracy projections for interstation position determinations using the GPS differential technique range between a few millimeters for baselines of a few kilometers, to a few decimeters for baselines of up to perhaps 5000 kilometers. These accuracies assume observations of from thirty minutes to two hours in length.

POTENTIAL USES OF GPS FOR CIVIL WORKS

Quality Control. As the Corps of Engineers continues to contract for a greater and greater proportion of their surveying and mapping product needs, while at the same time the number of in-house survey personnel decreases, quality control will become of greatly increasing concern. A GPS antenna may be placed over a mark in the middle of a traverse and used to check a contractor's conventional survey for accuracy. If two intervisible points are checked, an azimuth may also be determined.

Elevations Along the Mississippi River. There is evidence that the whole of the Mississippi river basin is sinking, so that elevation benchmarks along the river are suspect. Since measurements of levee profiles are dependent on these benchmarks they too may be in doubt. GPS could provide an elevation reference which is not subject to these errors. GPS could also be used to measure subsidence of marks along the river with reference to marks 100 kilometers away. In combination with an inertial survey system, measurements of levees would be better able to find low spots. It should be understood that GPS measures elevations to a different reference plane than a conventional leveling survey, and thus is not completely suitable for establishing absolute elevations. However it should measure changes in elevation with full precision.

Elevation Reference for Tidal Gauges. In the same way that GPS could be used to control elevation benchmarks along the Mississippi river, it could be used to check tidal gauge elevations along coastlines. In addition, techniques are being developed that may be useful for determining absolute elevations in certain cases. These might be used to determine the elevations of offshore islands, or wherever it is difficult to determine elevations by conventional methods.

Control in Remote Areas. GPS could be conveniently used to bring first or second order control into remote areas without the usual ground traverse or triangulation net. Present costs for such surveys are in the neighborhood of $750 to $1200 per point.

Mapping Control. Resource mapping using aerial photography requires adequate ground control. This may be provided by TRANSIT in areas where conventional control is difficult to obtain.

Utility Line Control. Particularly in remote areas, a utility line route is selected from aerial photographs. The laying out of this route on the ground is greatly facilitated by utilizing doppler satellite methods.

As you might note, most of the above uses are for surveys which do not require high accuracy. Forty centimeters is not good enough for most types of surveying presently performed by Corps surveyors. Further, the time required for the measurement of a single point is a full day of observations. The Global Positioning System increases the accuracy of these measurements while at the same time reducing the time required for an observation.

THE NAVSTAR GLOBAL POSITIONING SYSTEM

The NAVSTAR Global Positioning System (GPS) was originally conceived as a tool for military sea, land, and air navigation. The system consists of the three parts: the satellites, the ground control network, and the user equipment.

Present plans call for the system to be implemented using 18 NAVSTAR satellites, with three in each of six orbital planes. The orbits are approximately 20,000 kilometers above the earth, giving an orbit period of 12 hours. With this configuration, a user should be able to receive signals from at least four NAVSTAR satellites simultaneously at almost any point on earth (except the extreme polar regions), at any time.

Information from the satellites is transmitted by means of a pseudorandom code which is controlled by a cesium clock within the satellite. The user equipment measures the time of arrival of the pseudorandom pulses by adjusting its internal code generator to phase match the code being received from the satellite. Then, by knowing the time of arrival of signals from four satellites, it is possible to solve for position in three dimensions plus an accurate value for time. A lesser quality clock is required for use in the receivers.

GPS may be used in several modes, although all may not be available in the future to the civil surveyor. Direct access to the pseudorandom code in a high accuracy navigation mode (approximately 10 meters) may be denied to all but a few civil users, although a lower accuracy mode (200 meters) should be available.

The technique of most interest to Civil Works users is the **differential** mode. In this mode, two or more GPS receivers simultaneously receive signals from the same set of satellites. The resulting observations are subsequently processed to obtain the interstation difference in position. If one of the receivers is placed at a known position, the

Continuous Monitoring of Dams. There is also an interesting potential for continuous monitoring of dams and other large structures using GPS. In this case several antennas would be permanently mounted on the structure with another, reference antenna, mounted on stable ground a few kilometers away. Relative, two dimensional movements could be detected at a level of less than five millimeters.

COST

The approximate cost of a basic NAVSTAR GPS receiving and processor unit will initially be about $300,000, but will probably drop to the $125,000 range by 1987. Cost of a single receiver alone should be about $50,000, and this will be the most probable purchase for the private surveyor. He would operate the single receiver at various sites as a remote station while a service company in his area would man the reference station continuously. The service company would also processe his collected data and provide him with the results. This might be the desired entry level for a Corps District as well.

THE FUTURE

It is becoming increasingly accepted that any future land records and information system will be based on a nationwide geodetic framework. This would not only provide an accurate and efficient means for referencing data, but also a uniform and effective means for distributing land records. In this regard, GPS represents a potential major breakthrough in providing efficient control densification. At the same time it poses the question as to whether densification is necessary.

The probable future configuration for use of the NAVSTAR GPS system by the private surveyor will be to have a single base station (which may be operated by a service company) at a convenient point within a limited geographic area, and any number of mobile stations operated by private surveyors (who may either own or lease the units). Survey reference would always be to the geodetic control network without the necessity of bringing control to the site in the conventional sense.

IN CONCLUSION

The NAVSTAR Global Positioning System has been shown to be an accurate method for measuring positions on the face of the earth in as little as one-half hour. As the system becomes more widely available, it will find widespread use in the civilian and Corps civil works areas. Several of the Corps Districts have already used the system under a lease arrangement with excellent results. The Corps will find NAVSTAR GPS an increasingly valuable tool in its future.

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